Z-99 The Next Generation of Shared Seismic Models for R&D

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Abstract

We have created several elastic 2-D models and are currently defining a complex 3-D elastic salt model for distribution to the international research community for use in the calibration of AVO, polarization filtering, tomography, multicomponent seismic analysis, converted wave tomography, and seismic attribute analysis. We have also obtained the release of several real 2-D data sets corresponding to the 2-D models to test the robustness of any new techniques. In addition to the synthetic seismograms generated over these models, we will release the model definition of layers and rock properties to the research community so that others may modify them to include features beyond the scope of our current effort, such as gas clouds, fractures, and diagenetic changes. Finally, we expect these models to serve as a test bed for improving the computational efficiency of elastic modeling as a goal in itself.

Introduction

Geophysicists use seismic models for two major purposes - to help design the seismic acquisition program to provide optimum subsurface illumination, and to calibrate new seismic processing and imaging algorithms. Because of its speed, asymptotic ray theory is the method of choice for 3-D acquisition studies. However, full wave equation models which simulate source generated noise as well as signal, are usually preferred when calibrating seismic processing and imaging algorithms. While many companies and research institutions have excellent internal wave equation seismic modeling capabilities, two models have dominated the technical literature during the past decade. Both of these models were designed in joint industry/national laboratory collaboration, with the results being made publicly available to industry, research centers, and universities alike. The first of these models was the 2-D Marmousi experiment, coordinated by the Institut Français du Pétrôle. Modeled after a structure offshore Angola, the finite difference (FD) seismic data generated over this model have served as a benchmark for testing 2-D velocity analysis and imaging algorithms (Versteeg, 1994). The second model was the 3-D EAGE/SEG salt model, coordinated by scientists at Los Alamos, Sandia, Oak Ridge, and Lawrence Livermore National Laboratories working with representatives of the international petroleum industry. Modeled after a salt structure in the shallow water Gulf of Mexico, this model has served as a benchmark for testing 3-D velocity analysis and subsalt imaging algorithms (House et al., 1996). During 2001, some two dozen presentations at the EAGE and SEG meetings were still using these model datasets.

Even though they are 'old', these models are still an excellent means of calibrating new velocity analysis and imaging algorithms. However, since they were generated using the (less expensive) isotropic scalar wave equation rather than more complete anisotropic viscoelastic wave equations, they have little value in calibrating new advances in AVO, 'elastic' inversion, polarization filtering, converted wave tomography, shear wave splitting analysis, Q compensation, and multicomponent imaging. In addition, to our knowledge there are no publicly available models that simulate acquisition over rough topography or along the ocean bottom.

True calibration takes place only with real data, replete with inconsistent coupling, side-scattered noise, and near surface heterogeneities. Our goal is to provide the research community with a full suite of data calibration tools, beginning with layer geometry and lithology definitions, gridded models, ray theoretical results from commercial ray trace software, acoustic FD models, and elastic FD models, as well as the corresponding real data.

Methodology

Our modeling project has two components, a shorter-term, 2-D modeling component, and a longer-term, 3-D modeling component. The 2-D models, with the exception of an elastic version of the IFP Marmousi model, will have corresponding real 2-D seismic data associated with them. The 2-D models include lithologic cross sections, gridded Vp, Vs, density, and (for some) anisotropy and attenuation. A representative shot gather of real data is shown in Figure 1. The elastic Marmousi model, which we are currently calling 'Marmousi 2' shown in Figure 2, provides a summary of our goals. With the exception of the salt velocity, which we found to be a little too high, all P velocities and densities, as well as layer definitions are nearly identical to those of the original model. In order to obtain shear velocities, we first associated each layer with a particular lithology (sand, shale, marl, salt, and of course, water). Next we inserted some hydrocarbon targets - gas-charged and oil-charged sands, and obtained modified vp, vs, and density through well-established fluid substitution equations. The original Marmousi model was structurally complex. We extended the model by 50% in each direction for two reasons - first, to add some stratigraphic targets in a structurally quiet area, and second, to allow the simulation of very long offset data now used in AVO analysis, elastic inversion, and the imaging of steep flanks. Our final change was to place the entire model in deep (500m) water, allowing us to compare processing and imaging flows that use modern multicomponent ocean bottom cables to those obtained by more conventional surface streamer acquisition.

At the submission of this abstract, we currently have two models defined: Marmousi 2, and the one corresponding to the data in Figure 1. We are completing negotiations with oil and service companies to release one or more multicomponent OBC datasets in the Gulf of Mexico over salt structures, a very long offset (8km) data set for AVO analysis in the presence of anisotropy, also in the Gulf of Mexico, and a conventional data over rough topography with tilted anisotropic shales in the Canadian Rockies. UH will also generate models corresponding to two crustal scale surveys: an active source survey collected across New Zealand and a passive source seismic survey collected across New Mexico. In addition to calibrating new developments in anisotropy and multicomponent analysis, we feel these models will allow university researchers and students to better justify collecting more densely sampled surveys amenable to exploration style processing.

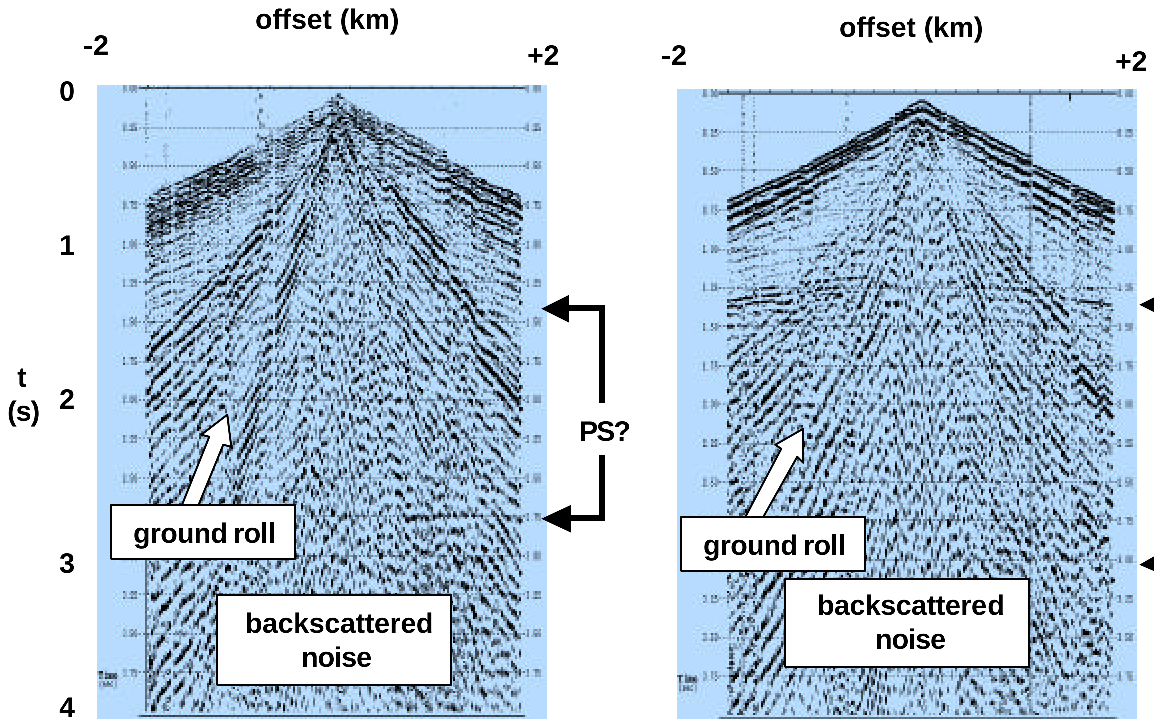

FIG. 1. Representative shot gathers from a 2-D multicomponent survey collected in the Fort Worth Basin, TX, USA. (a) inline horizontal component, and (b) vertical component. PP and PS indicate reflections. Data courtesy Mitchell Energy.

Our 3-D model will be built upon an earlier 3-D model designed by a joint venture of four international oil companies to aid multiple elimination and subsalt illumination studies at the Gulf of Mexico shelf edge. We will modify this model by adding stratigraphic features including channels and fans along the deformed interfaces, thereby broadening the model's use. In addition to providing a test bed for seismic imaging and velocity analysis, the calculated data will be used to calibrate and validate current seismic attribute technology, including coherence, dip/azimuth, spectral decomposition, impedance inversion, and AVO. Calculation of synthetic data from the selected models will exploit the computational resources provided by the national laboratories using their high order FD algorithm. In order to obtain useful results that could impact other's research as early as possible, we will begin by simulating sparse multicomponent ocean bottom cable acquisition rather than the more-expensive-to-model surface streamer acquisition.

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References:

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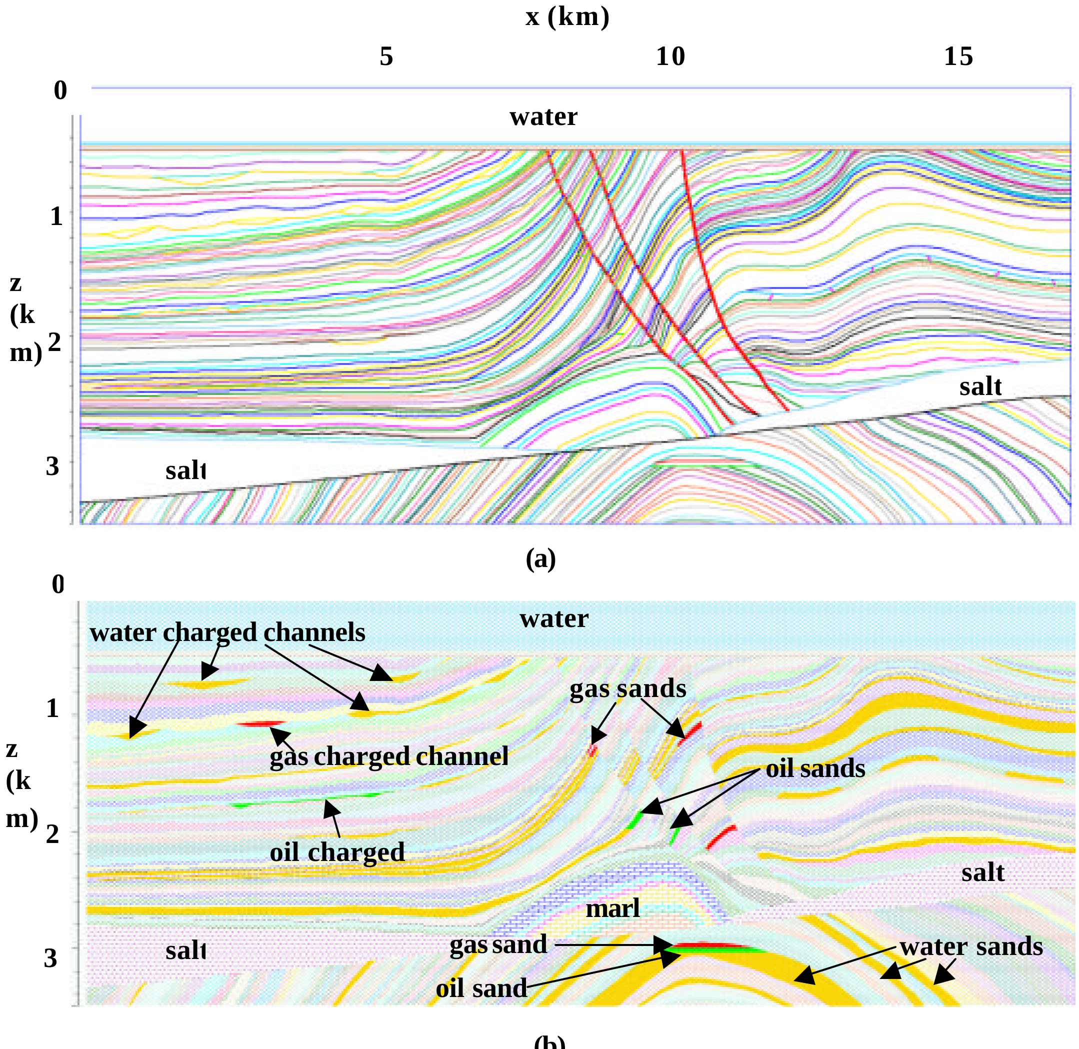

FIG. 2. (a) Layer and (b) lithologic definition of the Marmousi 2 model. Except for the salt, the p-wave velocities and nearly identical to those of the original model described by Versteeg (1994). Densities and shear velocities are obtained using fluid substitution and rock physics equations for shales, sands, and carbonates. Model building software courtesy of GX Technology.